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THE DESIGN OF REFRIGERATION, THERMAL INSULATION AND AN EQUIPMENT FOR HEALTHY RIPENING OF MANGO AND BANANA WITHOUT USING HARMFUL CHEMICALS

D. RAMESH BABU[1,2], K. V. NARASIMHA RAO[3] & SYAM KOLATI[4]

[1]*Assistant Professor, Department of Mechanical Engineering, S R Engineering College, Warangal, Telangana, India*

[2]*Research Scholar, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Andhra Pradesh, India*

[3]*Professor, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Andhra Pradesh, India*

[4]*Assistant professor, Department of Humanities and Sciences, S R Engineering College, Warangal, Telangana, India*

ABSTRACT

Mango and Banana need to be ripened artificially when they are harvested before ripening process starts on the tree or plant. This need arises due to the large distances fruits need to be travelled before reaching the consumer points. If fruits are riped naturally on trees, the journey of fruits in the soft stage leads to damage of fruits before it reaches the consumer. A banned chemical powder of calcium carbide is being used by traders in the fruit and vegetable markets due to lack of knowledge and unavailability of safe ripening technologies. This paper discussed the safe ripening practices for mango and banana fruits along with the technical design and commercial aspects of refrigeration systems, ripening systems, control systems, PUF panel insulation structure for a ripening chamber facility. Use of ethylene gas is recommended by scientists for the safe ripening of mango and banana. Technical specifications for all these systems are prepared and presented in this paper for use by industries.

KEYWORDS: Food Security, Refrigeration Systems, Design, Mango, Banana, Artificial Ripening, Insulated Panels & Healthy Fruit Ripening

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Original Article

INTRODUCTION

India is the largest producer of banana and mango in the world. 29.72 million Tons of banana and 18.43 million Tons are produced in India in the year 2014. India exports mango and banana to several other countries. Mango and banana being perishable commodities need cooling and preservation technologies to keep the fruits for a long time to benefit the farmers for better price realization during less demand in the market and high production time. Farmers also must get the benefit of off-season prices. At the same time consumers also get the benefit of availability of fruits during off-season. At present Indian farmers are not able to take the benefits even though India is the largest producer of these two fruits in the world. This is due to lack of infrastructure, knowledge along with technical details to the farmers and interested entrepreneurs. This paper presents the data of technical specifications, components and machinery to be used for a suitable refrigeration and ripening systems for mango

and banana storage. Several preservation methods like pre-cooling, cool store, drying, etc. are used to preserve apples to benefit farmers to get a good price while selling [1]. Several researchers investigated on the cooling aspects and heat and mass transfer to remove field heat of fruits by forced air cooling [2], hydrair cooling [3,4,5] Cold Storage (CS) or Controlled Atmosphere storage (CAS) is used to store fruits and vegetables for longer periods [6,7]. In the CS, fruits are cooled to low temperature and maintained at that temperature to increase its life. In CAS, fruits are kept at low oxygen and high carbon dioxide level apart from low temperature and high relative humidity. Beneficial effects of ethylene ripening were studied by several researchers and optimum ethylene concentrations were derived.

The important processing operations carried before mango and banana ripening are: sorting, quality segregation, size grading, and packing in the storage boxes (either CFB boxes or plastic perforated crates) [8]. Sorting indicates separating the non-storable fruits from the good fruits. Non-storable fruits include: Over matured/ripened, heavily bruised, spoiled/damaged due to mishandling during plucking or transportation or insect damaged fruits. Grading means segregating the fruits based on the size and colour. Mangos and bananas are stored in separate storage chambers due to the fundamental properties of rate of respiration [1]. This helps to get an optimum shelf life.

Refrigeration systems are to be designed suiting the temperature requirements of mango and banana. From preliminary experiments it was found that ripening of mango and banana at 24-28 deg C is appropriate. However this depends of the type, variety and pre-harvest practices.

Traditionally traders and farmers are using harmful chemical named calcium carbide for ripening due to its availability at low cost. Several harmful effects on human health due to carbide ripened fruits are reported by Asif (2012) [9]. The toxic effect of calcium carbide is reported by Mohd Danish et al (2015) [10]. Ripening systems using ethylene are designed to suit the concentration requirements for banana and mango. An ethylene generator is used to make controlled release of ethylene typically to maintain at 100 to 150 ppm in the ripening chambers. The ethylene generator contains ethylene liquid to vaporize, ethylene sensor to measure and control the ethylene level in the ripening chamber.

LITERATURE OVERVIEW

Gomej-lim (1997) investigated on mango fruit softening and made studies on the postharvest physiology [10]. Brinson (1998) discussed the cell wall and carbohydrate changes during maturation are important from the point of view of marketing and storage [11].

Prasanna et al (2007) in a review article explained about the fruit ripening which is genetically programmed, highly coordinated, and an irreversible phenomenon involving a series of biochemical, physiological, and organoleptic changes, which finally makes a soft and edible fruit in the ripen state with attributes as desired by consumer [12].

Ramesh Babu and Satish Kumar (2017) discussed about the pulp and gel made from muskmelon. The ripe muskmelon made into pulp and visco-elastic properties are measured and reported. Using sodium alginate the pulp is made into gels and visco-elastic properties are measured and compared with raw pulp [13].

Kader (2002) has discussed the fundamental processes in the post harvest quality and related physiology of several horticultural crops especially the fruits. Issued related to bio-chemical, physiological changes are discussed in detail [14].

Sandeep Chauhan and Ramesh Babu (2011) conducted experiments on apples using botanicals for determining the effect of various leaves and extract of botanicals to extend the shelf life. Various plant leaves/ flowers used as coatings. Drake leaf extracts (10, 20%), Neem leaf extracts (10, 20%), Marigold flower extract (10, 20%), Spearmint leaf extract (10, 20%), and Semperfresh (control 1.5%) were investigated. Neem, Melia, Mentha, Walnut, Banna, Basooti, and Camphor were used as cushioning material in the packing boxes. The Drake leave extract was found to most effective in preservation of apple with minimal losses. They reported that Drake leaves were the best cushioning material [15].

Ashraf-Ur-Rahman et al (2008) discussed about the about artificial ripening of fruits in many parts of the world including Bangladesh. They explained about the natural ripening process on trees and use of ripening artificially to hasten the process of ripening. During transportation and carrying from one place to another place, the ripe fruits are prone for the damages due to soft fruits after ripening leads to quick rottening. So fruit traders pick unripe fruits & use certain methods to increase the shelf life of them. They reminded the use of ethylene as a fruit ripening agent. They discussed the inappropriate use of carbide to ripe fruits and suggested ethylene ripening solutions [16].

Ramesh Babu (2014) discussed about technological aspects of controlled atmosphere, cold storage, ripening chambers for Indian varieties of fruits and vegetables [16]. Several equipment and control systems along with material handling and electronic equipment are available [1, 8, 16-21].

MARKET POTENTIAL

At present banana and mangoes are ripened using carbide, which is harmful to the human health due to the toxic nature of the chemical. The traders found using this because of easy availability of carbide and no strict government regulations till recent past. Now the Government issued orders of banning of carbide. The right alternative is using ethylene gas, which is a natural agent. The fruits liberate ethylene during its ripening, when ripened naturally. The fruits are always harvested in advance to the ripened stage, to accommodate the transportation to the markets. As the fruits are harvested at green colour stage, artificial ripening is necessary to ripe them. Use of ethylene makes the fruits ripe naturally with good colour and safe for the consumption. The consumer awareness of safe and healthy fruits, increasing and the government banned the carbide usage for ripening purpose, there is a huge market for this concept. The concept of ethylene ripening is not new. Several states in north India have been using since last 5 to 6 years.

BASIS AND PRESUMPTIONS

- The Project is based on 24 hrs working a day & 300 working days per annum (with 4 to 5 days of the ripening cycle per batch per chamber)
- The value of the civil works has been taken in the project cost.
- The cost of machinery and equipment indicated in the report refers to a particular make and are approximate.
- The provisions in respect of consumables, personnel and overheads etc., has been made at the prevailing rates and are approximate only.
- The rate of interest has been made@ 14% per annum.
- The labour charges are based upon prevailing local market

- The ripening is done on chargeable basis to the farmers and traders and we will not be buying or selling the fruits at initial few years of the project

IMPLEMENTATION SCHEDULE

The main activities in the implementation of the project have been listed below and the average time for implementation of the project is estimated at 5 months as many activities can be taken up simultaneously.

Table 1

1.	Preparation of project report	1 month
2.	Registration and other formalities	1month
3.	Sanction of loan	1 month
4.	Purchase of machinery and equipments, etc.	2 months
5.	Installation and Electrification	2 months
6.	Construction of shed	2 months

TECHNICAL ASPECTS

Process Outline

- The fruits (Mango or Banana) transported from the orchards will be ripened in the ripening chambers to get the desired colour and sweetness and sent to the fruit markets. The ripening process using ethylene takes 4 to 5 days time for each batch i. e a chamber of 15 Metric Tons will be ripened at once.
- The ripening chamber will have the following features:
- An air tight chamber to prevent ethylene loss. This will prevent ethylene from
- entering unwanted areas like other chambers
- The chamber is made of insulated panels to control the temperature inside and arrest the cooling loss outside atmosphere
- The refrigeration system is provided to keep the fruit temperature at 20 to 28 deg C based on the type and variety of the fruit.
- A small heating system is also provided to support during winter conditions
- Proper air circulation is provided by fans, to keep the fruits at uniform temperature and atmosphere conditions
- High humidity is maintained by installing a Humidification system in each chamber
- An ethylene generator and ethylene measure system is provided to maintain the required ethylene composition in the air with in the chamber.
- An automatic ventilation system is provided to vent for the excess Co2 release from the chamber

Ripening Capacity per Annum

Fruits 21,00,000 kg per annum (average 7000kgs per day and 300 working days)

Future Products

Papaya and citrus fruits like lemon, oranges

- **Motive power** **:** 10 KW and Power Requirement of the unit is 15 HP
- **Pollution Control** **:** There is no pollution generated from the process.
- **Building** :-Build up area for the plant and machinery will be 600 sq. yards and working area/loading-unloading area is 100 Square yards.
- Cost of shed and other civil works : - Rs. 6,00,000/- aprx

TOTAL PROJECT INVESTMENT

a. Fixed capital	
i. Chambers and machinery	Rs. - 14,60,000/-
ii. Civil work	Rs. - 6,00,000/-
iii. Electrification, Power Supply and DG Set	Rs. - 3,00,000/-
b. Working capital	Rs. - 1,50,000/-
Total project cost	Rs - 25,10,000/-

Address of Chambers, Equipment Suppliers

- M/s. Infracool, 4276, Sector-23A, Gurgaon
- M/s Nilkamal ltd, cold store division, New Delhi
- M/s Isopan, cold store division, Gurgoan
- M/s Bluestar, Bangalore/Hyderabad office cold store division

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- The provisions in respect of consumables, personnel and overheads etc., has been made at the prevailing rates and are approximate only.
- The rate of interest has been made@ 14% per annum. .
- The labour charges are based upon prevailing local market
- The ripening is done on chargeable basis to the farmers and traders and we will not be buying or selling the fruits at initial few years of the project

Specifications of the Ripening systems

A 30 Metric Tons capacity ripening chamber's specification are prepared and presented below. The facility will have two chambers of 15MT capacity each

Chambers Capacity : 30 MT

Each Chamber : 15 MT

Chamber Dimension : 28.0 ft x 15.0 ft x 10.0 ft

Chamber Construction

Wall, Ceiling & Door : PUF Panels

Material : PUF

Density : 40 ± 1 kg/m3

Thickness : 80 mm

Floor Insulation : Expanded Polystyrene

Thickness : 10O mm

Door Size : 2200 mm(H) x 1200mm(W)

Door Type : Sliding

Details of Operating Parameters

The facility is designed to work on following parameters

Temperature : 10 to 28 deg C(depending upon application)

Relative Humidity : 90 to 95%

Humidifier : Steam Type

Ethylene Level : 100 to 150 ppm

Ethylene Generator (VENTAC/CATALYTIC/GENET) - 1 Nos.

Type : Portable

Capacity per Room : up to 300 m3

Ripening Liquid Consumption : 1 liter / 4 TO 12 hours(Adjustable)

Dimensions (in mm) : 315 x 250 x 350

Power Input : 230V, 50 Hz

C02 Level : below 1%, Supply and Suction fans

Operated automatically with timer.

Basis of Design for Heat Load

Dimensions : 28.0 ft x 15.0 ft x 10.0 ft

Insulation Thickness : 80 mm

Ambient Temperature : 45 Deg C (Maximum)

Room Temperature : Set Points ± 1.5 Deg C

Relative Humidity : 90 to 95 % RH

Product Incoming Temp : 30Deg C

Product Loading : 15 MT / day /chamber

Pull Down Time : 24 hrs

Refrigeration System Details

It is proposed to use Direct Expansion Freon Based System for the project. We propose to use two twin independent systems each with separate compressor for most efficient working during both periods of Peak Load and Steady State Load. Compressors are selected to maintain desired RH inside the CA Chamber.

Each system will comprise of the following:

Table 2

A.01	**2 Nos**	Single Stage Scroll/Reciprocating Compressor	
		Data for compressor:	
		Refrigeration Capacity	18.0 Kw
		Evaporating temperature	5°C
		Condensing temperature	55°C
		Refrigerant	R 22
A.02	**2 Nos**	Air Cooling Unit (Cu. Cu.-AI)	
		Capacity(kW)	20
		Air Volume (m3/h)	26428
		Air temperature (on / off) (°C)	7.5/5
		Refrigerant	R 22
		Evaporating temp	5 deg C
		Fin material	Aluminium
		Distance(mm)	7 mm
		Casing material	sendzimir galvanized - natural
		Air direction	horizontal - draw through
A.03	**2 Sets**	Freon Control Valve comprising of Stop Valves on both Suction & Discharge Lines. Solenoid Valves on both Suction & Discharge Lines, Dual Manifold, Safety Relief Valve, Special Control System to control RH inside the chamber.	
A.04	**1 Lot**	Copper Piping of minimum 18 g and thicker based on size & UV protected cross-linked insulation for the same.	

Bill of Quantities & Price Schedule

Table 3: Bill of Quantities & Price Schedule

Insulation Work				
S. NO	**Description**	**Qty**	**Unit**	**Value**
1	PUF Panel - 80 mm Thick with accessories	215	sq. m	
2	Floor Expanded Polystyrene-100mm	80	sq. m	
3	DOORS-Sliding Type	2	nos	
				6,50.000.00

Refrigeration Work				
S. NO.	**Description**	**Qty**	**Unit**	**Value**
1	Evaporator - Capacity: 20 KW	2	No.	
2	Compressor Package Scroll/Reciprocating Compressor Package Capacity: 18 KW	2	No.	
3	Condenser In-built with compressor package	2	No.	
4	Refrigerant Piping Work	1	Lot	
5	Insulation Work	1	Lot	
6	Drain Water Piping	2	Lot	
7	Valve Station	2	Lot	
				6,80,000.00

Electrical/Ethylene Generator/C02, C2H4 display/Humidifier				
S. NO.	**Description**	**Qty**	**Unit**	
1	Cabling & Wiring for equipments	1	Lot	
2	Internal Lighting of rooms	4	no.	
3	Ethylene Generator with first lot of liquid(5 Itr)	1	No.	
				1,30,000.00
	Total			**14,60,000.00**

(Rs. Fourteen Lakhs Sixty Thousand Only)

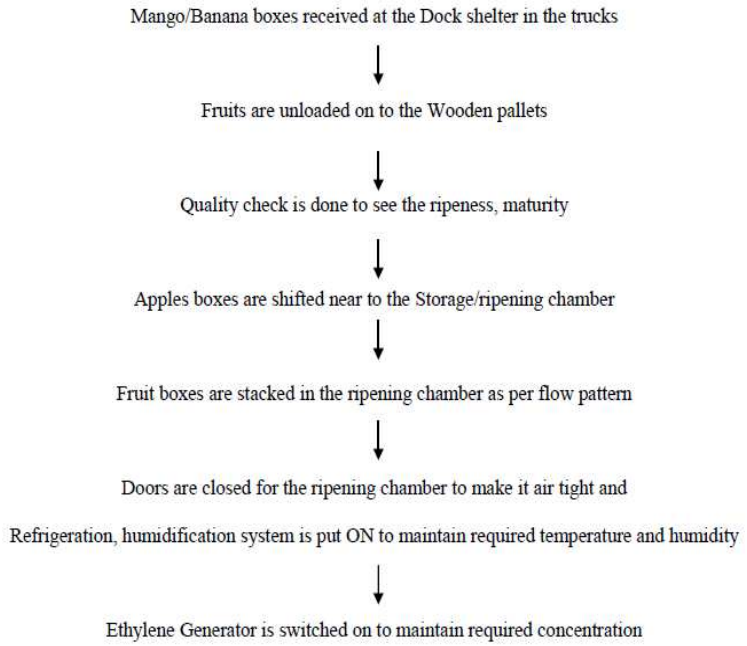

Figure 1: Flow Chart of Mango/Banana Ripening

MEASUREMENTS

Measurement of Firmness

Firmness is measured using a Penetrometer (Model FT327) [37]. Firmness is expressed in pounds/Lbs. The relevant instrument is shown in Figure 4.

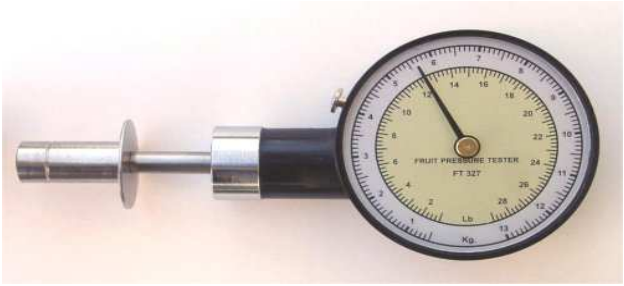

Figure 2: Penetrometer for Measurement of Firmness of Fruits

Figure 3: Bananas Stacked in Perforated Crates (Make: M/s Blue Star)

Figure 4: Ethylene Generator

CONCLUSIONS

Mango, banana and citrus fruits can be successfully ripened without using any harmful chemicals. The technical details given in this paper will help to setup new industries for preservation of these fruits using refrigeration, Insulations and ethylene ripening equipment will help to ripen the fruits safely. This will also help the farmers and fruit traders to follow the safe practice and in a larger perspective a commercially feasible and healthy fruits to the humans. It can be concluded that a 30Mt ripening chamber can be built with properly calculated and designed systems with a financial

budget of Rs25.1lakh approximately including civil costs and working capital. Further work can be done to find the optimal concentration of ethylene and temperature conditions for different varieties of fruits along with commercial viability studies.

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